All the Vanessids, including *Polygonia c-album* (not regarded as a migrant) have a disposition to wander about, and as *P. atalanta* is so strong on the wing its general distribution seems to be sufficiently explained, in the absence of direct evidence of true migration, by its notorious vagrant habits. It certainly seems to be impartial as to the direction of its long distance flights and may be observed on occasion flying fast on an undeviating southerly course. The value as immigrant records of observations of *P. atalanta* in this country is also so dependent on the question of whether the species is capable of surviving the winter here that it is important that the evidence in favour of its being a local resident should be carefully examined. I have noted below a few significant facts which have come under my notice.

(1) Kept in captivity by myself throughout winter and remained vigorous in spring—also by H. W. Head (*Entom.* Nov. 32).

(2) Seen ovipositing in April (Penmaenmawr, N. Wales).

(3) Found drying wings beside empty pupa case in early July (Penmaenmawr) not same year as (2).

(4) Regularly seen in fresh condition in July in many places in N. Wales.

(5) Observers frequently remark on excellent condition of specimens seen in June-July, when *P. cardui* is invariably very worn. The possibility cannot be ignored that such specimens may be bred from ova deposited in April by hibernated butterflies. It will be appreciated that the North Wales observations so early in the year carry greater weight than similar records from the south coast and indicate that local conditions are favourable for the species to maintain itself there from year to year. I would suggest that it is desirable to explore the subject further.

(Letter from H. W. Wilson to Capt. T. Dannreuther, 7.xi.32.)

An Account of my Studies in the Biology of Pieris rapae.

By ORAZIO QUERCI.

This year I have made some experiments to get data about the life-history of *Pieris rapae*, Linné, and some other polygenetic species of butterflies. I found an excellent collecting place on the Parkway, near the Art Museum, which by solicitation of the Academy of Natural Sciences of Philadelphia was left to grow wild.

Last year, at Philadelphia, the butterflies began to emerge in April, but in 1932 the weather was bad in early spring and we saw the first Lepidoptera on the wing on May 15th. From that day until now we have collected without interruption taking about 7000 specimens which were brought home still living; some were set in cages, with their host plants, where they laid eggs; others were mounted. Eggs, larvae, chrysalids and imagines were also tried in different temperatures in refrigerators and incubators kindly put to my use by several institutions.

I. Breeding from the Eggs.

(A). The butterflies taken in the field were set in a cage with wild flowers and food plants. Some females laid eggs, and those laid on the same day were reared all together. The lots of eggs

obtained in different days were kept separated. Both in spring and summer the mean temperatures varied from 65° to 75°F, and almost always the eggs hatched in four or five days. In each lot there were a few larvae which grew very rapidly and became full grown in seven days; for others, although being laid by the same female on the same day, full development required 8 to 14 days. The butterflies emerged from the chrysalids in from one to two weeks. From May 19th to September 15th we reared more than 100 lots of eggs, and the whole life-cycle was never shorter than 18 days, and longer than four weeks.

(B). In this fall the temperature was lower; the eggs hatched in 5 to 7 days, the most rapid larvae grew in 10 days, and the imagines emerged after 8 days. The minimum required in development of the imago from the egg is now 23 days instead of 18. I do not yet know the maximum because the other chrysalids of the same lot have not yet emerged.

(C). On May 19th and 20th we obtained two big lots of eggs from specimens of the first brood taken in the field. Those eggs hatched in 5 days, and one of the larvae, from the eggs laid on May 19th, hatched on the 23rd, pupated on May 30th, and a female emerged on June 7th. That female was not well developed and died without laying eggs. On June 8th one male and one female emerged at home from eggs laid on May 20th; they mated on the same day of their birth and the female laid eggs from June 9th to the 13th, which hatched from the 13th to the 17th of the same month. A few larvae, from the lot of eggs laid on June 9th, pupated on the 20th, and the imagines emerged from them on June 27th.

The male and female of the second brood, emerged on June 8th (mounted after their death), are large, with pale and reduced pattern at the tips of the wings; their descendants, born on June 27th and following days are smaller, with a very black and extensive pattern. All the *rapae* which emerged in our cage on June 27th from the home born specimens of the second brood, were placed in another cage, where the females laid many eggs for six days. I wished to mount those specimens of the pure-line third brood, but they were so badly broken, while flying in the cage, that I preferred to set in my collection one male and one female, which emerged on June 29th, from the same lot of eggs, which looked very like those emerged two days before and from which I had six lots of eggs from June 27th to July 2nd.

At the beginning of July it was hot: the thermometer reached up to 93° F., and all the larvae of five lots died. Placing the larvae in an ice box and in front of a fan, a few of them, from the eggs laid on June 29th, were able to survive, and pupated. Two females emerged on July 19th, another female and two males on the 21st. These five specimens of the pure-line fourth brood are very small with pale and reduced pattern. The three females laid many eggs, but, in spite of every care, only three larvae survived the heat and pupated. One male and one female of the pure-line fifth brood, emerged on August 9th, mated and the ♀ laid 19 eggs only. Another female emerged on the 13th, but did not lay eggs as the male of the same lot was dead.

The pure-line *rapae* of the fifth brood are larger than their parents

and with a very black pattern ; they resemble their grand-parents of the third brood.

The 19 eggs, from which I expected specimens of the sixth brood, hatched in four days, the larvae became very big, but all died on August 22nd, on a sultry day when the thermometer reached up to 88° F. Thus my series of pure-line breedings remained uncompleted before reaching the sixth brood, but my experiment proves that if I have obtained five consecutive broods from May 20th to August 9th, at least three other broods may occur before the frost in October.

II. Temperature Experiments.

(D). Eggs, larvae and chrysalids tried for 5 to 20 days at 0° F., and later gradually warmed at 30°, 50° and 70° F, died when they returned to normal temperature.

(E). The spring eggs, larvae and chrysalids died when tried for 25 days at 30° F. The experiment was made again with summer specimens, which remained one month at 30°, and later were gradually returned to the temperature of our rooms. About a half of the eggs hatched, the larvae survived and the chrysalids emerged. Another big lot of eggs was tried for 45 days at 30° F. Very few larvae hatched when they returned to normal temperature.

(F). At the temperature of 45° to 50° F, most eggs of a big lot hatched there after 14 days. The larvae were left in that rather cold room with fresh plants. They grew very little and in about one month died.

(G). Some chrysalids, placed in a room at 50° F, emerged there after 27 days, but the Lepidoptera were not able to spread their wings.

(H). Many butterflies of different species remained at 60° F for 18 days. All the males died ; most females survived and laid eggs when they were placed in our cages.

(I). A lot of eggs placed at 98° F, hatched there in 4 days. All the larvae died almost at once, also if they were taken out from the incubator they died.

(J). Most larvae in our breeding cages turned yellow and later died when the temperature reached 85° F for a few hours.

(K). It seems that also in the field, many larvae die when it is hotter than 90° F. As the heat does not injure the chrysalids, the butterflies continue to be plentiful, for about one week, after a wave of heat, later they become scarce for about ten days because the high temperature kills both the small and big larvae. Comparing the results of our collecting with the data of the Weather Bureau of Philadelphia, I am finding a perfect concordance.

The scarcity and often the total absence of polygenetic species which sometimes I observed for ten and more days while collecting in Southern Europe, and which I supposed to be intervals between one brood and its following, are but the effect of the waves of heat.

III. Life-history of Pieris rapae at Philadelphia, in the year 1932.

The American authors relate that *rapae* begins to emerge sometimes by the end of March, and often in April. This year the weather was fine in winter but it became bad in early spring, until mid May. On the 15th of this month we took some butterflies.

They continued to emerge until May 20th, and later, until the 26th, only worn specimens were on the wing. The duration of the flying period of the first brood was 12 days. The lack of Lepidoptera in the last days of May was not due to the climate as the weather was fine.

In the afternoon of June 2nd we saw a few *rapae* in the City, and the following morning we collected two males and one female. The second brood had begun to emerge 19 days later than the first emerged specimens of the first brood. This period corresponds with the result of our breedings.

To know when the second brood might cease to emerge I had the support of the data of our breedings: minimum of duration of the larval stages 18 days, maximum 28 days, but I was not sure that, both in the cages and in the field, the period would have been the same. A useful indication I might perhaps get by looking at the forms. While most *rapae* of the first brood are small and with a pale apical pattern of reduced extent, many specimens of the second brood are very large, the grey pattern is a little wider and the ocelli are bigger. Fresh *rapae* of this exuberant form were taken until June 22nd, that is 28 days later than May 26th, when we saw the last female of the first brood laying eggs. Worn *rapae* of its largest form were found until June 28th. The flying period of the second brood was 27 days and it was 15 days longer than that (12 days) of the first brood.

In accordance with what I believe to be a rule (when the temperature does not change) the earliest *rapae* of the third brood should begin to emerge on June 19th, but on that day it was raining. The following day there was 63 per cent of sunshine, and we took some *rapae* a little smaller than those of the prevailing form of the second brood but with a wide and very black pattern. Specimens of this form became more frequent later. From June 20th to 28th we saw specimens both of the second and third brood flying together and when, on June 29th, the second brood ended, the black-spotted *rapae* of the third brood remained on the wing alone until July 7th, when the striking form of the fourth brood began to emerge.

I expected that the *rapae* of the third brood would have disappeared from the field by the end of July, instead the specimens with a prominent black pattern continued to emerge in August, September and until now. For some time I was unable to understand why the duration of the third brood might have been so long, while at home *rapae* continued to emerge in no more than 28 days since its egg was laid. Only later I knew that the deep black-spotted *rapae* is also the prevailing form of the fifth brood. This is confirmed by the three pure-line *rapae* of the fifth brood, which emerged in our cages and which are black (not grey) at the tips of their wings.

With the support of these data I suppose that the third brood, began on June 19th or 20th, and ended on July 24th. Some females continued to fly until the 30th, or so. By the end of July the butterflies in our cages had lived long and laid many eggs. The probable flying period of the third brood was 44 days, about 17 days longer than in the second brood.

The fourth brood of *rapae*, which is rare in the hot and barren

countries of Southern Europe and of which we found no specimen in North Africa, has been plentiful at Philadelphia this year. We have taken at least 600 specimens of that pretty form. Last summer the country was always verdant: almost as luxuriant as we have seen in the Tropics in the raining season. At the Weather Bureau I have been told that such a fine summer has not happened in this City for 30 years.

Many specimens of the fourth brood, we collected in the field, are as small and with as pale a pattern as the five pure-line *rapae* which emerged in our cage from the cross of a male of the third brood with a female of the same generation. This seems to prove that the small size of some polygenetic species is produced by heredity and not by environment. Until now I had believed that the butterflies smaller than usual might be the ones which had grown in distress, but I must change my opinion. The largest number of small *Pieris rapae*, *Pontia protodice*, *Colias philodice* and *C. eurytheme* were taken, this year, after the field had been for a long time (during their larval stages) the most luxuriant I have seen in the Temperate Zone. From my breedings I have learned that when the larvae of the *Pieridae* are in distress they die.

The nice *rapae* of the fourth brood began to emerge on July 7th; fresh specimens were found until August 28th, and some worn females until September 3rd. The flying period of this brood has been 59 days.

Many individuals of the fourth brood (form *phaiosoma*, Verity) in my collection look to be from the cross of both third brood male and female, as this last brood remained to fly alone for some time last June. In August we found some very small *rapae* with a black (not pale grey) pattern, which are perhaps the mongrels between the third and fourth broods, which flew together in July.

For the fifth brood I am unable to check whether it began on July 25th and ended on October 7th, according to my forecast, or not. When it began, there still were on the wing specimens of the similar third brood, and in September it mixed with the eighth brood, the form of which is, I believe, the same as in the third and fifth broods. Almost every day, from June 20th until now, we have taken some *rapae* with a very black pattern; this is the most frequent form of the species, being of the third, fifth and eighth broods. Also among the so-called second brood there are specimens which resemble those of the third, etc. This occurs for a cause which I will try to explain later.

The large *rapae* of the second brood did not fly after June 28th; after that day we found only smaller (third and fifth brood) and much smaller (fourth brood) specimens on the wing; also their mongrels were not large. On August 12th a few white *rapae*, which looked like those of the second brood, were found. The appearance of this showy form, which we had not seen for 45 days, happened just when I had foreseen that the sixth brood should begin to emerge, and this allows me to suppose it may be the peculiar form of *rapae* when two pure-bred specimens of the fifth brood cross together or when the third brood crosses with the fifth. Some large *rapae* have been taken almost every day from August 12th until now, but they have not been plentiful, because the fifth brood, having flown together with the

fourth, which is small, produced mongrels of reduced size. I was not able to get in my cages any specimen of the sixth brood, as the 19 larvae, I had from the pure-line *rapae* of the fifth, died after the wave of heat of August 22nd, but from that breeding I learned that the pure sixth brood *rapae* must be large, as the larvae which grew more rapidly and that were trying to pupate when the heat killed them, were very big.

The pure bred *rapae* of the seventh brood, which began to emerge on August 29th, have been scarce, as their pure bred parents had not been plentiful and had mated with those of the fourth and fifth broods and their mongrels. I have no positive data to establish which may be the peculiar form of the seventh generation ; I suppose that some small *rapae*, like those of the fourth, but dusted with black scales (owing to the increasing humidity in the fall) may be those of the seventh when one pure-bred male of the sixth crossed with a pure-bred female of the same brood. This year these dwarf *rapae*, the smallest in my series, emerged from chrysalids made by larvae which, in August, had lived among the most luxuriant vegetation. Also in this case, the very reduced size seems not to be produced by environment but by heredity. I think these specimens, flying in September and also in these last days (October 1st to 10th) can not be still those of the fourth brood which should be ended by the beginning of last September.

On August 31st, after the eclipse, a wave of heat (up to 95°F) arrived in this country and continued for some days. In spite of that the *Lepidium virginicum*, which is the plant that the larvae of *rapae* prefer to eat, remained verdant everywhere, and the period, 18 to 28 days, for the metamorphosis, remained unvaried for the specimens which we bred in September. I suppose that the eighth generation began to emerge on September 18th, but I cannot prove my assertion. I also suppose that the pure bred *rapae* of the eighth brood may be as black spotted as those of the third and fifth broods.

What I observe is that, in spite of the considerable hybridisation, *rapae* has never been so variable as in September : dwarf specimens of the seventh flew together with the giants of the sixth and the black-spotted individuals of the fifth. If some *rapae* of this last form are those of the eighth brood, is not sure but likely.

By the middle of September until now the weather has been unsettled and the field is not so verdant as in summer. The butterflies in the cages die quickly, laying very few eggs. The wave of heat at the beginning of September has lowered the number of butterflies on the wing. However the larvae, which we are rearing, continue to grow almost in the same time as in spring and summer. Perhaps the emergence of the chrysalids will be delayed, but if the weather continues fair for a few days longer, a ninth brood may occur this year although last spring the lepidoptera began to appear very late in the season.

What I have tried to explain above can be shown by the following table where (1) for every brood, I record (2) the day on which the specimens of each brood probably began to emerge ; (3) the not so probable

days on which the last specimens of every brood emerged ; (4) the day on which they ceased to fly and to lay eggs ; and (5) the presumed duration, in days, of each brood :

(1)	I	II	III	IV	V	VI	VII	VIII	IX
(2)	May 15.	Jun. 2.	Jun. 19.	Jul. 7.	Jul. 25.	Aug. 12.	Aug. 29.	Sep. 18.	Oct. ?
(3)	May 20.	Jun. 22.	Jul. 24.	Aug. 28.	Oct. 1.	(*a*)	(*a*)	(*a*)	(*a*)
(4)	May 26.	Jun. 28.	Jul. 30.	Sep. 3.	Oct. ?	(*a*)	(*a*)	(*a*)	(*a*)
(5)	12	27	44	59	75 ?	(*b*)	(*b*)	(*b*)	(*b*)

(*a*) A few chrysalids of the VI, some of the VII, many of the VIII and most of the IX brood will go over winter, emerging in the spring of 1933.

(*b*) It is not possible to state the duration of the flying period of the last broods, which will occur after the winter pause.

In accordance with the data of the preceding table, the broods of *Pieris rapae* have probably emerged and overlapped (at Philadelphia and in the very regular season of 1932) as follow :

from May 15 to May 26, first brood ;

from May 27 to June 1, interval between the first and second brood ;

from June 2 to June 18, second brood alone ;

from Jun. 19 to Jun. 28, second and third ;

from Jun. 29 to Jul. 6, third alone ;

from Jul. 7 to Jul. 24, third and fourth ;

from Jul. 25 to Jul. 30, third, fourth and fifth.

from Jul. 31 to Aug. 11, fourth and fifth ;

from Aug. 12 to Aug. 28, fourth, fifth and sixth ;

from Aug. 29 to Sept. 3, fourth, fifth, sixth and seventh ;

from Sep. 4 to Sep. 17, fifth, sixth, and seventh ;

from Sep. 18 to Oct. ?, fifth, sixth, seventh and eighth ;

from Oct. ? to Oct. ?, sixth, seventh, eighth and ninth.

Now I hope to be able to get the data which are still missing ; later I will check better, with the support of my collection of more than 2000 *rapae*, 300 *protodice*, 200 *philodice* and *eurytheme*, which seem to emerge in the same manner as *rapae*, all mounted and labelled.

I regret not to have been able to breed all the larvae from the eggs laid by one single female of *Pieridae*, to see whether all the imagines are equal among them, or not. I succeeded with the larvae of *Papilio* and *Phyciodes*, when I obtained imagines 98 per 100 of the laid eggs, but the larvae of *Pieridae* are very frail, and from more than 12,000 larvae, which I tried to rear, I had no more than 250 chrysalids.

Also in the field the mortality must be considerable when it is very hot, and still more when it is hot and dry. Some authors say that one female of *rapae* can lay more than 200 eggs ; also supposing that the eggs are only 25 of which 15 males and 10 females, if each egg might produce the imago there would be 10 females at the second brood, 100 at the third, 1,000 at the fourth, 10,000 at the fifth, 100,000 at the sixth, 1,000,000 at the seventh, 10,000,000 at the eighth. This does not happen ; the butterflies instead of being plentiful are scarce chiefly because the heat killed most larvae.

IV. Observations.

I feel almost sure that the data I record for the beginning of the first to the seventh brood are right. At any rate the error can be no more than one day or two. From May 15th to September 10th the temperature lowered to 50°F only thrice (May 19th and 23rd, and June 8th) during the night. The minimum mean temperature varied from 61·3° in May to 69·4° in August, and in those conditions, the larval stages went ahead with the greatest regularity.

The data which I quote for the end of every brood are tentative, because in each lot of larvae, which we have bred, those which grew slowly always died. The search in the field for the last living female of every brood is not an easy task, not only because it is hard to find her, but also because I based my investigation looking at the form.

That the form of *rapae* should change from a generation to its following is a simple opinion which I base on the fact that the specimens of the second, third, fourth and fifth brood, which I obtained from consecutive breeding, changed at each brood, and that their change corresponding with it had occurred in the field some days before. However I must notice that my series of pure-line *rapae* is very poor. I had many chrysalids of the second brood, most were tried in temperature experiments and in many cases died; also of the third brood I had many pupae, some died when tried at low temperature, others emerged but the specimens were ruined in the cages; of the fourth brood I obtained five specimens, of the fifth only three. This is all.

The study of the variation, referred to the identification of the broods, is also doubtful because also the specimens of the first generations are not alike among themselves in my series of *rapae*, the earliest emerged almost at the same time from May 15th to 20th, there are a few, which look different from the others and seem to have not been produced by chrysalids, which had gone over winter. Among the *rapae* of the second brood, emerged in the first fortnight of June, when certainly the real third brood specimens had not had time to emerge, I see some specimens, with very black spots, which look like those of the true third brood, which surely did not began to emerge before June 19th.

The presence of these specimens which apparently have advanced one brood over their time of emergence, allow me to suppose that either the eggs, or the larvae, or both, might go over winter together with the chrysalids.

From my experiment (E), related at p. 170, I have learned that very few eggs, of a big lot, survived when kept 45 days at 28° to 30°F. At Philadelphia, this year it was never cold in winter for long. The coldest days were: Dec. 8th, 1931, Jan. 23rd, Feb. 1st and 16th, March 9th, 1932, on which the thermometer was 23°F for a short time. Perhaps some eggs, laid in the last fair days of October, 1931 and remained unhatched, were able to survive, and hatched during the first days of April, when it was 67° and 73°F. The larvae did not die, as is shown in my experiment (F) at p. 170, and pupated about on April 23rd, when the max. temperature was 72 to 79°F., but were not able to emerge until middle May, when it was 77° to 87°F. The

presence of these specimens from the egg-cycle are a trouble when they are mixed with those of the chrysalids-cycle in the first brood. Now I am arranging to keep many eggs to see wether they will hatch next spring, or not.

V. Conclusion.

My experiments are still incomplete, but at any rate I can state that:

1. *Pieris rapae* and many other polygenetic species are ready to be prolific at any time of the year, as soon as the temperature allows their eggs to hatch. In Southern Portugal we collected many polygenetic butterflies in January of 1928.

2. The cold injures only when it is, probably, below 15°F. Otherwise it only delays the metamorphosis.

3. The intensive heat, above 90°F produces a terrible massacre of larvae, but does not injure either eggs or chrysalids.

4. When the mean temperature is above 60°F, a new brood occurs about every 18 or 19 days. (I have not yet full data for the fall.)

5. The duration of every brood is at least 15 days longer than that of its preceding brood, and therefore all the broods, save the first, overlap.

6. This year, at Philadelphia, with a uniform and favourable season, but shorter than in most years, certainly eight broods have emerged, and probably a ninth may occur. When the butterflies emerge here from April to October there may be 10 or 11 broods. In Southern Spain and Portugal, and in the southern portion of the United states, perhaps 14 broods occur in most years.

Philadelphia. *October 11th*, 1932.

SCIENTIFIC NOTES AND OBSERVATIONS.

Length of Life of the Imago of Orrhodia ligula.—Of this species South (*Moths Brit. Is.*) says "It lives through the winter . . . . but does not seem to turn up at sallow catkins in the spring," Adkin (*Moths of Eastbourne*) "It is doubtful whether it ever lives through the winter." In this connection it may be interesting to note that I took a specimen at Chipstead, Surrey, on January 30th of this year, at rest on a hawthorn by night, which was fed with sugar at intervals and lived until mid-April.—J. A. Downes.

"Food" of Cucullia verbasci Larvae.—This year I collected a few larvae of *C. verbasci* at Box Hill. They were kept in a cardboard honey carton, which as usual had a thin layer of wax on its surface. One day the larvae were given insufficient food, with the result that they nibbled through the wax and started on the cardboard underneath. A friend of mine had a somewhat similar experience with this species. He enclosed them in a muslin sleeve, again with insufficient food, and found next day that they had eaten a hole in it and escaped.—Id.